DARPA Robotics Programs

Dr. Scott Fish

DARPA RHEX

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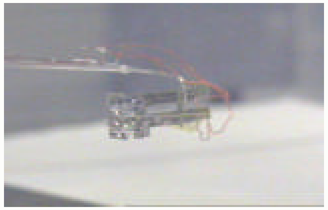
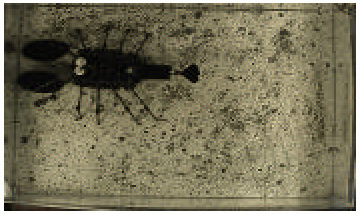
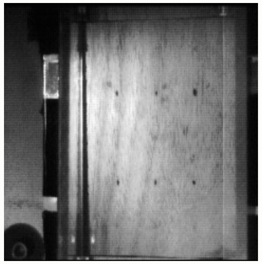
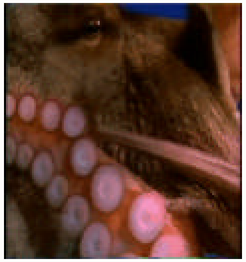
Making Robots More Like Animals

Today


Rhex: a stable legged SUGV
FCS ready

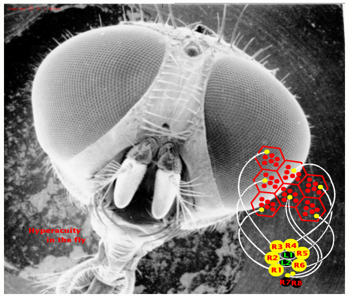
The Future

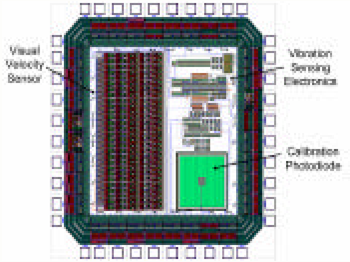
What do legs, wings, fins offer Defense mobile systems?

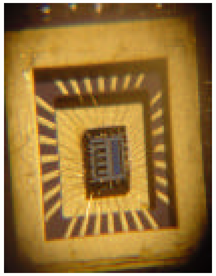
<u>There are many hard problems in robotics, look to biology for</u>:
- ***Exploiting Robust Dynamics***
- ***Building a Brain***
- ***Integrate Sensors and Communications***

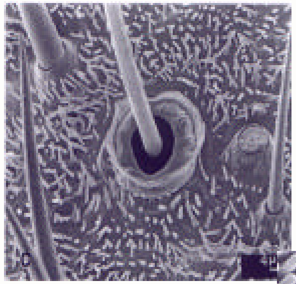
Use Biomimetic Sensory Feedback for Higher Level Dynamic Mobility

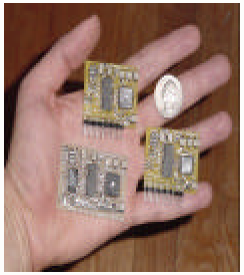
- Visual Odometry and Optical Flow
  - Track motion through combined feature triangulation and image flow
  - Improved dynamic motion models will improve performance
- Proprioception
  - MEMs based gyros for positional information (yaw, pitch, roll)
  - Strain gauges for force feedback
  - Mems Antennal structures as bump sensors and contact guidance

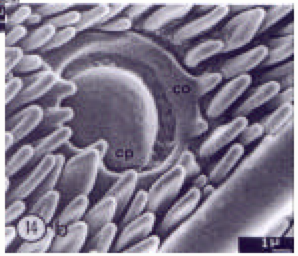


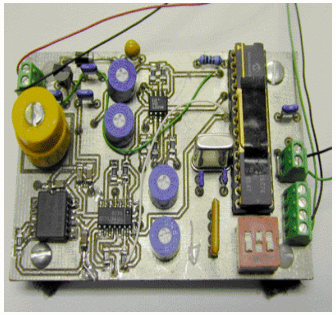


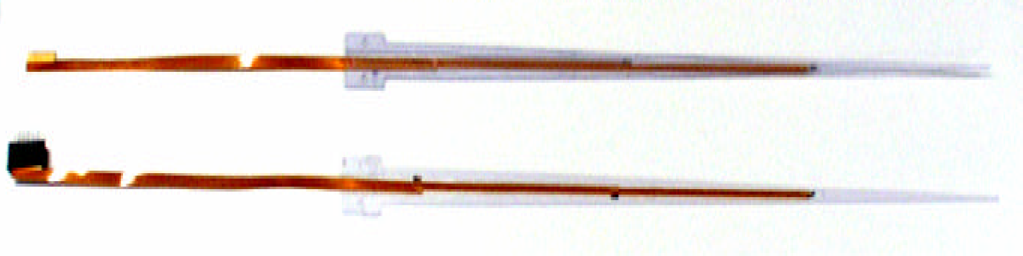












DARPA Mobile Autonomous Robot Software (MARS)

Doug Gage, IPTO

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MARS Technical Approach

Intervention

User interfaces structured so that humans can assist robots when needed

Interaction

Natural information exchange between robots and humans -- as teammates, bystanders, supervisors, and operators

Perception

Sensor-based algorithms to sense, interpret, and "understand" salient environmental features

Learning and Adaptation

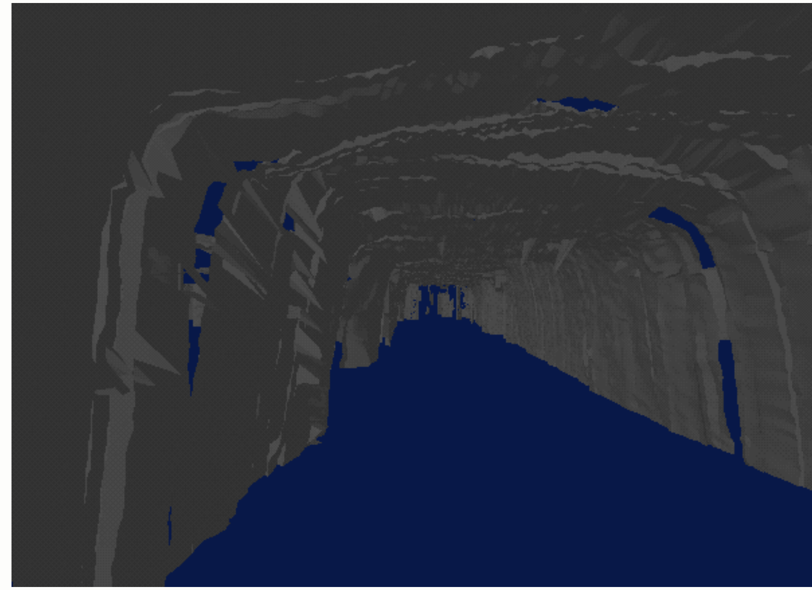
Techniques to acquire knowledge through reinforcement, supervised, or imitative learning

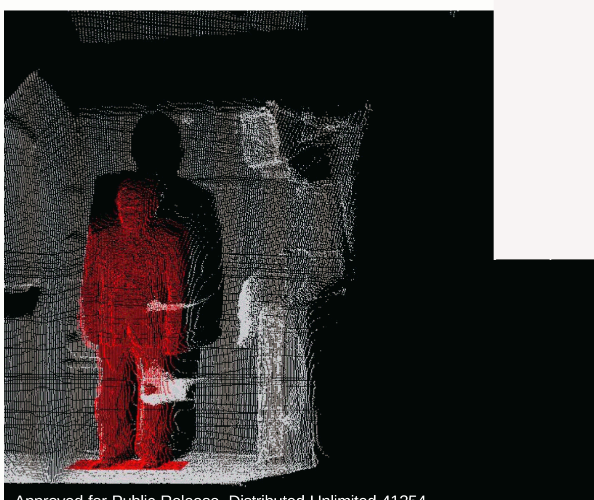
Behaviors and Architecture

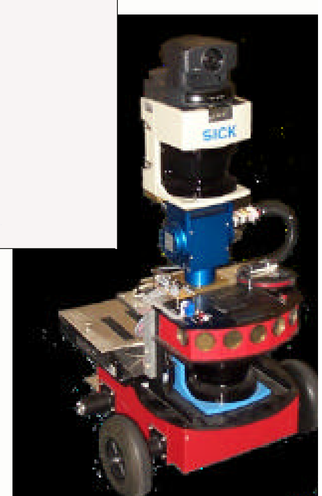
Software components and structures to perform robot tasking

Perception

- **Mapping Complex Indoor/Outdoor Environments**
  - Faster, more accurate, larger scale
- **Dynamic Environments**
  - Detection, Tracking, Modeling







The Carnegie Mellon

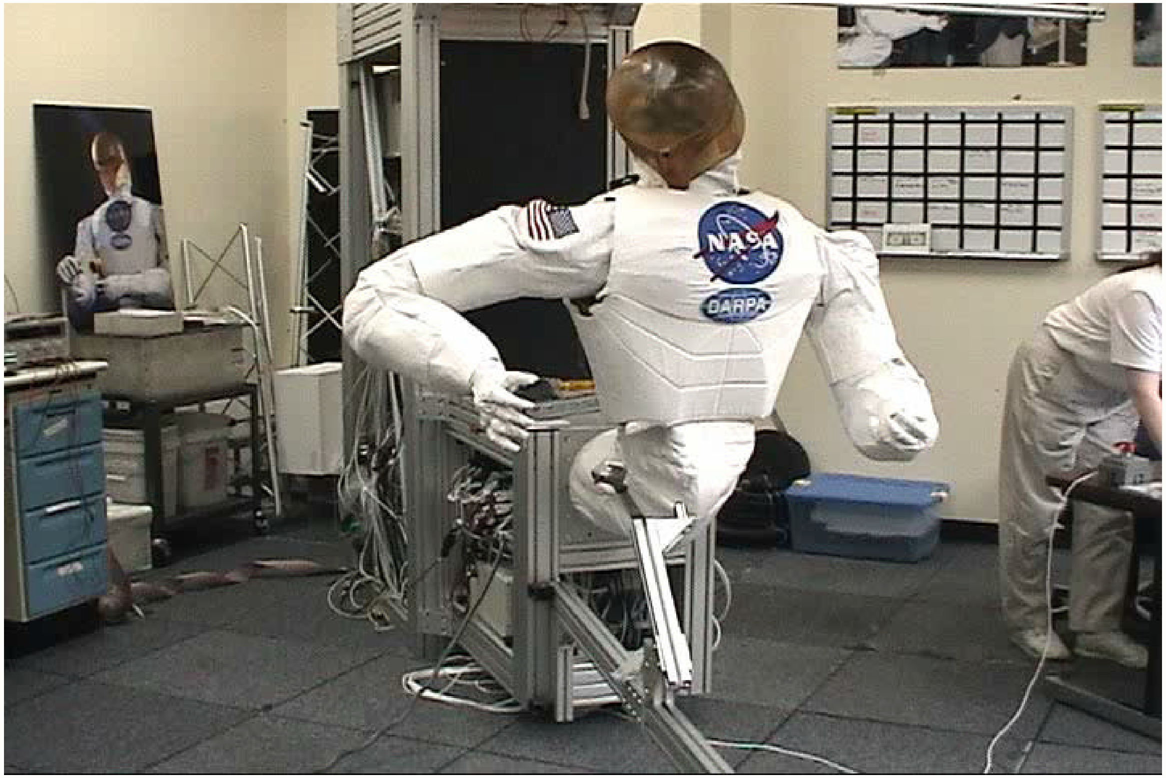
Robotic Mine Mapping Project

Sebastian Thrun, Michael Montemerlo, Dirk Haehnel, RudolphTriebel, Wolfram Burgard, Red Whittaker

sposored by: DARPA IPTO (MARS)

Interaction with Humans

- **Demonstrated supervised machine learning of autonomous task-level behaviors through full immersion teleoperation and off-line reflective analysis.**
- **Mobile Remote Workstation demonstrated long distance operation of Robonaut in Houston TX from MARS PI Meeting in Arlington VA.**



Approved for Public Release, Distributed Unlimited-41354

DARPA Grand Challenge: Open Source MARS Software

- **CarMeN (Carnegie Mellon Navigation Toolkit) integrated solutions to indoor robot navigation and mapping problems.**
  http://www.cs.cmu.edu/~thrun/3d

- **CMVision (CMU) library to perform general (i.e., and shape or color) obstacle avoidance**
  http://www.cs.cmu.edu/~jbruce/cmvision

- **YARP (MIT) utilities for programming abstractions used in the control of humanoid robots, an inter-process communication mechanism suited to stream large quantities of robot's vision data, and supports a distributed architecture where there is no "in charge" module**
  http://sourceforge.net/projects/yarp0

- **MissionLab v5.0 (Georgia Tech) multiagent robotics mission specification and control software using high-level military-style plans and executes them with teams of real or simulated robotic vehicles.**
  http://www.cc.gatech.edu/ai/robot-lab/research/MissionLab/

DARPA Grand Challenge: Open Source MARS Software (2)

- **XVision (Johns Hopkins Visual Tracking Software)**
  provides generic interfaces to a wide variety of camera systems, generic visual tracking primitives, and methods for combining tracking for complex situations.
  http://www.cs.jhu.edu/CIRL/XVision2/

- **Yampa (Yale) is a language having continuous time-varying behaviors and discrete event-based switching. "Arrows" are used to structure programs and improve efficiency.**
  http://www.haskell.org/yampa/

- **The GRL Language (Generic Robot Language) (Northwestern is a programming language for behavior-based robot controllers that supports a large subset of functional programming semantics for real-time control and signal-processing applications.**

  http://www.cs.northwestern.edu/groups/amrg/distributions/grl/grl-2.0.zip

DARPA Distributed Robotics

Elana Ethridge, MTO

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Distributed Robotics

Objectives:

- Small mobile robots
- Modular robots for physical reconfiguration
- Enabling technologies for :
  - actuation / locomotion
  - communication & sensing
- Demonstrate collective & cooperative behaviors with limited numbers of small robots

Challenges:

- Size
  - Mobility (ground clearance, obstacles)
  - Sufficient processing, sensing, power, communication
- Effective operation of small robots
  - Task -> behavior -> sensor
  - Tailored to the mission

DARPA Software for Distributed Robotics (SDR)

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SDR Technical Thrust Areas

- *Coordinated Behaviors*
  - Explicit sensor-based behavior and model-based control
  - Distributed (emergent) control techniques (*e.g*., analogous to potential field theory in mechanics)
- *Inter-robot Communications*
  - Lightweight energy-conserving networking protocols
  - "Pheromone" communication strategies
- *Human-robot Interface*
  - Explicit symbolic interface
  - Implicit embedded or stigmergic interface
- *Computational architecture*
  - Distributed processing
  - Proxy (off-board) processing
  - Hybrid (shared or hierarchical) processing
- *Lab & Field Experiments*
  - Control/Communications
  - Human-robot interaction
  - Technology transitions

DARPA PerceptOR

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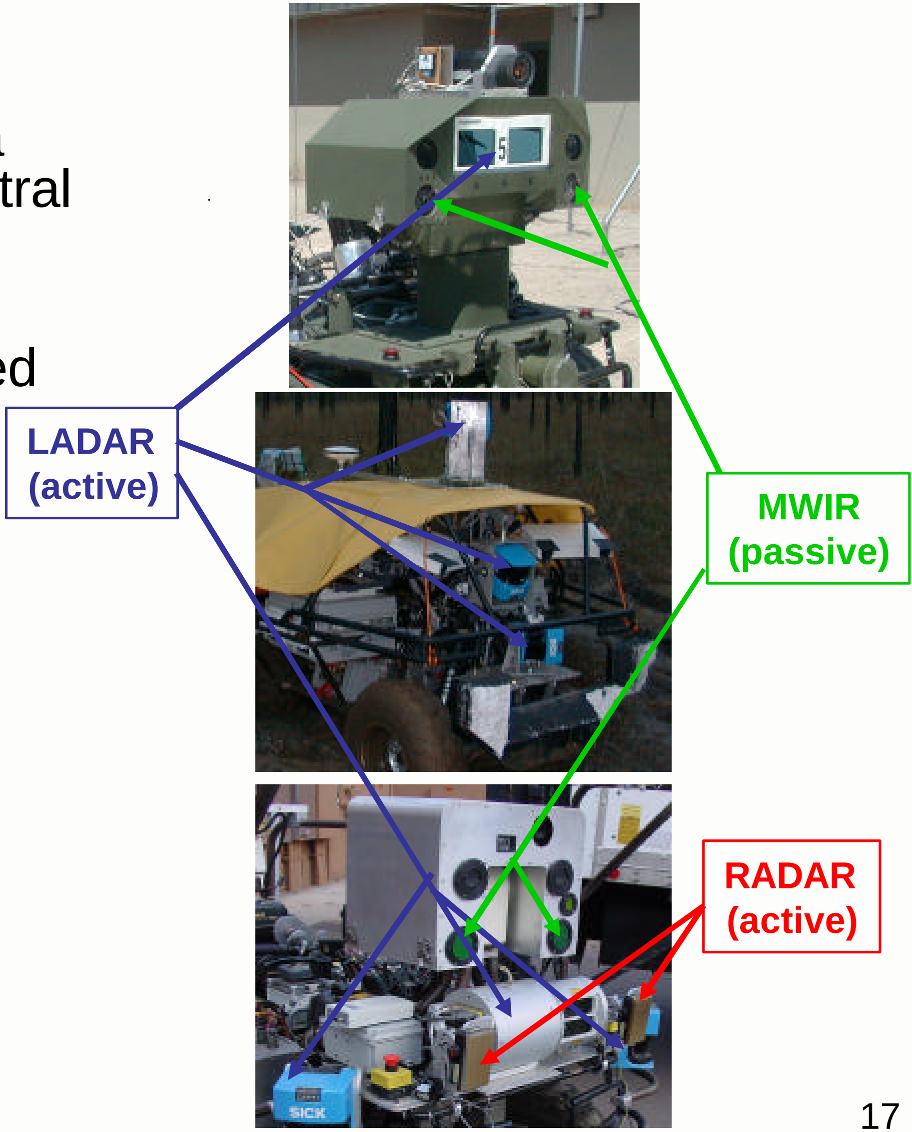
PerceptOR Program

- Perception for Off-Road Robotics *FY01-03*
- 3 Teams with complimentary approaches
- 4 Unrehearsed Field Experiments in <12 months!
  - 61 km of movement
  - 68 hrs of measured testing
  - Utilize small vehicle (commercial ATV)
  - Purposely operate vehicles in concealment terrain
    - Ft A.P.Hill, VA (woods, meadow, trail, winter)
    - Yuma, AZ (desert, spring)
    - Mountain Training Warfare Center, CA (alpine)
    - Ft Polk, LA (woods, meadow, trails, fall)
- Negotiating Phase III of Program Now!

PerceptOR Sensor Usage

- Scanning Ladar provides 3 Dimensional geometric information (day or night)
- Now getting good results with stereo (a passive sensing system) for 3D + spectral information
- Radar is good in bad weather but limited resolution
- New techniques with 2D cameras are being developed for 3D sensing while moving

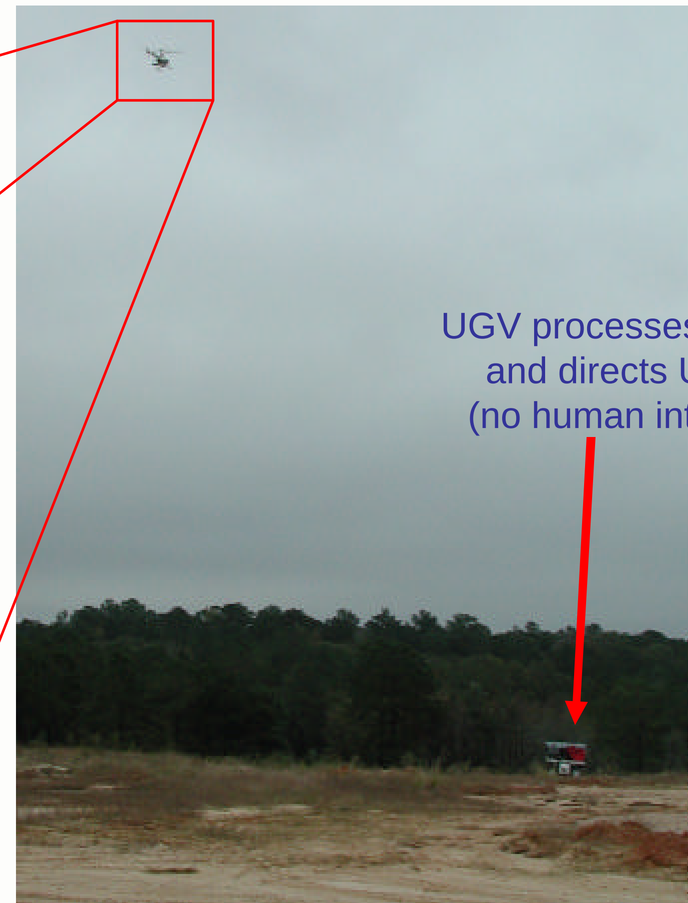


Operating Day or Night

UAV and UGV Autonomous Operation

- Real-time UGV/UAV autonomous coordination has been demonstrated for joint perception
- Process scaleable to higher altitude platforms

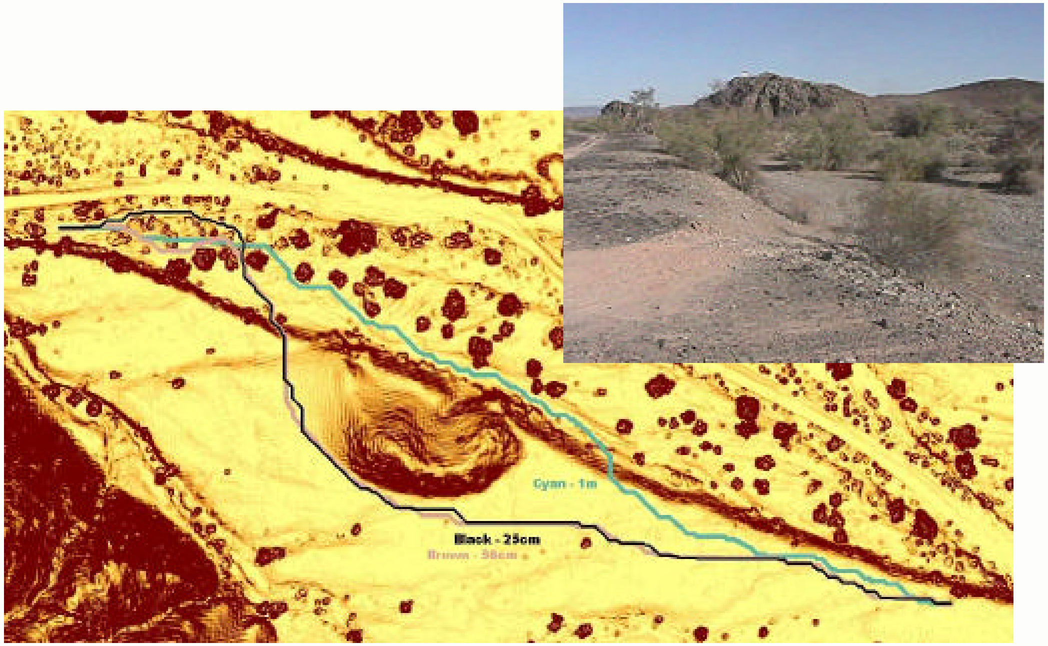
UAV with ladar/stereo
finds obstacles
ahead of UGV

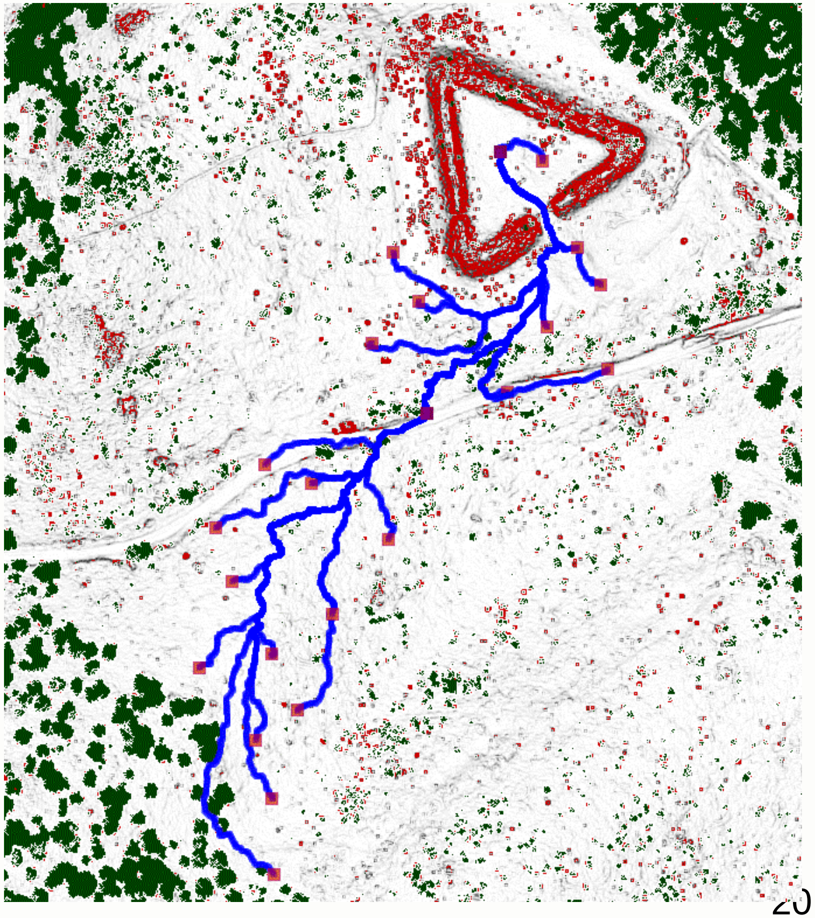


UGV processes UAV Data
and directs UAV flight
(no human intervention)

Prior Overhead Data Utilization

- Path planning is greatly assisted with Prior Overhead Data
- Have demonstrated autonomous re-planning onboard the vehicle
- Need to utilize this data to queue sensors and adjust perception/navigation settings





DARPA Unmanned Ground Combat Vehicle (UGCV)

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UGCV Program

- 3 year program started in FY01
- UGV design for FCS unconstrained by human crew
- 1.5 years of design analysis of 4 designs
- Prototype vehicles (6.5 ton, 0.7 Ton) just rolled out
- Metrics:
  - Endurance: 14 days and 450 km between re-supply
  - Mobility: 1 m obstacles @ slow speed
    0.25 m obstacles at moderate speed
  - Payload fraction: 25% of gross

2000 kg Payload

Carnegie Mellon University
Boeing
Timoney Technology
PEI

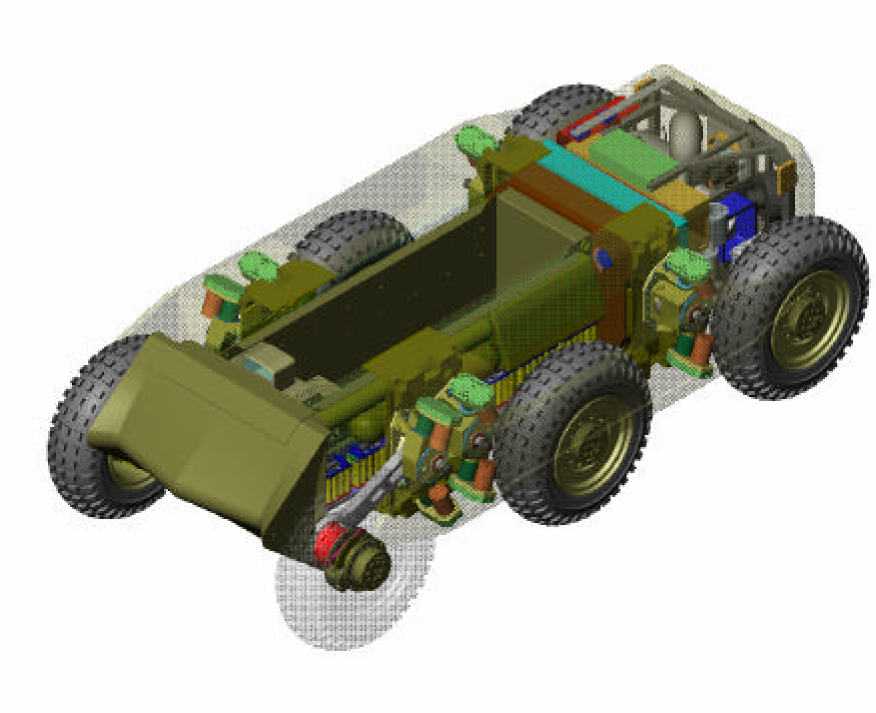
Lockheed Martin
Sandia
Rod Millen
BAE
MSE

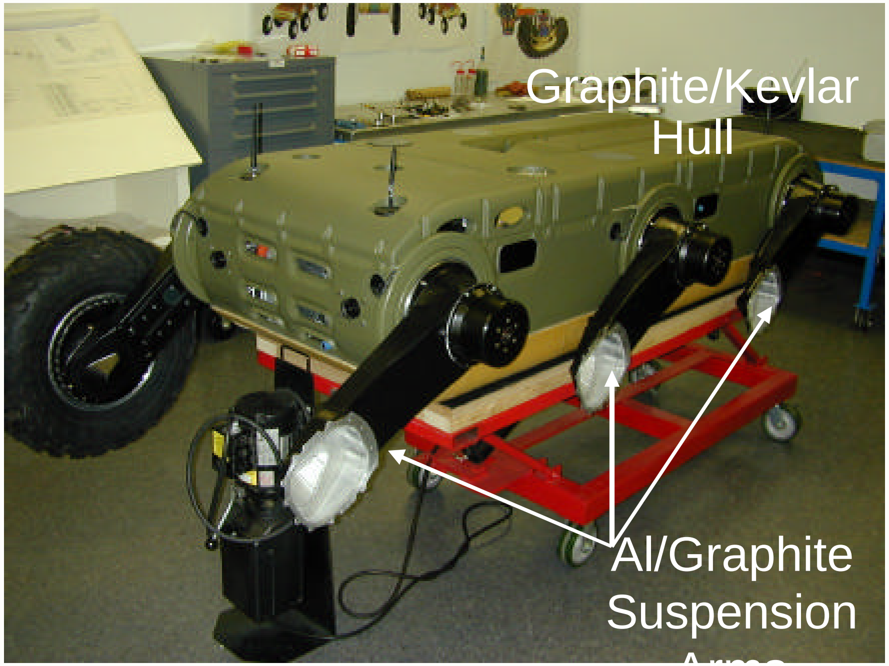
150 kg Payload

UGCV Advanced Technologies

Hybrid Electric Drive:
- Efficiency
- Damage tolerance
- Packaging
- Silent watch/Silent Mobility

Advanced Materials
- Weight savings
- Thermal properties
- Magnetic properties
- Fluid properties





Retiarius Rollout

January 22, 2003
Albuquerque, NM

Spinner Rollout

February 6, 2003
Pittsburgh, PA

Spinner Suspension Test Rig

Rock Climber Vehicle

Send Off

- Lots of robot research being done at DARPA
- Much still needs to be done
- DARPA pursues many different means to encourage Novel approaches
- Hope this has been helpful in understanding existing work
- Best of luck in pursuing your own special approaches